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A Field of Mangels on the Dairy Farm

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ROOT CROPS as a feed for dairy cattle are used extensively in northern Europe and Canada with good results. Their production has been limited in the United States to those sections of the country where, because of climatic or other conditions, corn cannot be grown successfully for silage. A root crop can often be grown for succulent feed where the number of cows is not sufficient to justify the expense of building a silo. There are many farmers in West Virginia who keep from 2 to 10 cows and for whom a silo would be too expensive, but who might well grow a root crop for succulent feed. Many dairymen in this state also, on account of the hilly condition of their farms, have only a few acres in the valley upon which to grow their succulent feed. A root crop might well be grown in such cases in place of silage because of the greater yield. To determine whether or not root crops could be grown successfully in the state and to compare their feeding value for milk production with that of corn silage, an experiment was started at the West Virginia Experiment Station during the summer of 1923 and was continued for a period of eight years.

REVIEW OF LITERATURE

Very little recent work in the United States has been reported in comparing root crops with corn silage as a feed for dairy cattle. It has been found that pound for pound the root crops are not equal to corn silage. This is as would be expected since corn silage contains a higher percentage of dry matter than do the root crops.

Some of the older studies indicated that corn silage was superior to the root crops as a feed for dairy cows even when fed on a dry-matter basis. Brooks *(2)* found that cows gave more milk and cream and gained more in weight when fed corn silage than when fed mangels, both being fed on the dry matter basis, and Hills *(6)* reported that 100 pounds of dry matter from corn silage produced 1 percent more milk and 4 percent more butterfat than an equal amount of dry matter from beets. Caldwell *(3)* found that it required from 0.2 to 0.3 lb. more digestible matter to produce 1 lb. of milk solids and from 0.6 to 1.9 lbs. more digestible matter to produce 1 lb. of butterfat when roots were fed than when silage was fed.

*Mr. Morrow resigned June 1, 1931.

More comprehensive investigations, on the other hand, point to the superior value of root crops. Thorne, Hickman, and Falkenbach *(13)* reported, after conducting four feeding trials, that the daily difference in milk flow was always in favor of the ration containing field beets—the difference while not large being conclusive—but they were unable to say that the dry matter of the beets was more effective as a cattle feed, pound for pound, than the dry matter of corn silage containing from 13 to 18 percent of grain. Waters and Weld *(14)* found that the feeding of roots increased the quality of milk over that obtained when corn silage was fed and concluded that the digestible matter in roots was of slightly more value for milk production than that of corn silage. Savage *(11)* found that for milk production one pound of dry matter in mangels was equal to 1.05 lbs. of dry matter in corn silage, and equal to one pound of dry matter in grain. Rothwell *(10)* found that the dry matter in mangels has 15 percent more feeding value for milk production than has corn silage. He also found that mangels had a supplementary effect when fed with corn silage. When fed alone mangels were worth only 60 percent as much as corn silage for milk production, but when fed in limited amounts in conjunction with corn silage they were 73 percent as valuable as corn silage. Shaw and Norton *(12)* also studied the supplementary effects of roots to silage and found that the addition of roots to an already complete ration further increased milk and fat production, indicating that mangels may be used successfully in the feeding for heavy milk production. Hills *(6)* also recommended them as an appetizer.

There seems also to be some disagreement in regard to the effect the feeding of mangels has on the percentage of butterfat. Among the early investigators Caldwell *(3)* and Brooks *(2)* both found that the milk produced when the cows were fed roots contained more fat than when they were fed corn silage. However, Waters and Weld *(14)* and Hicks *(5)* found that when the cows were fed roots the percentage of butterfat was slightly less than when corn silage was fed. Shaw and Norton *(12)* found no difference in the fat content by the two methods of feeding. It is interesting to note also that Thorne, Hickman, and Falkenbach *(13)* report that the feeding of field beets did not diminish the amount of water consumed, although fed in such quantities as to increase the water content of the ration by 30 pounds per day.

Brooks *(2)*, Thorne, Hickman, and Falkenbach *(13)*, Waters and Weld *(14)*, and Savage *(11)* all found that the cost of producing a pound of dry matter was higher with the root crops than with corn silage.

While there are some yields of the various root crops reported which run over 30 and even as much as 40 tons to the acre, the average yield would seem to be much lower than these figures. Hopkins *(7)* states that the average yield of roots for four years at eight Dominion Experimental Stations was 19.4 tons per acre, and that this yield was nearly twice as high as the average yield of all the

roots grown in the five eastern provinces of Canada, where it was only 10.5 tons for the same period. Moore and Wheeler *(8)* report that the three-year average at the Michigan Experiment Station was 19.6 tons for mangels, 18.2 tons for turnips, 16.04 tons for carrots, and 13.16 tons for rutabagas.

GROWING THE CROP

Root crops were grown on the Dairy farm at the West Virginia Experiment Station for six years upon a fairly fertile soil, capable of producing from 8 to 12 tons of corn silage per acre.

Fertilization The ground was well covered in late fall with from 10 to 15 tons of manure per acre. Where other than well-rotted manure was used, trouble with weeds was experienced during the following season. At time of planting from 200 to 500 pounds of complete fertilizer containing a fairly high percentage of potash was added. Lime was added in quantities to meet the lime requirement.

Preparing the Soil Whenever possible the ground was plowed in fall or during winter. As soon as workable in spring it was prepared for planting. The seedbed was prepared thoroughly by disking and harrowing frequently until the soil was fine and mellow. This was an important factor in killing weeds and grass with resultant saving of much labor later in the season. Just before planting a plank drag was used to level the surface for planting.

Planting The seed was planted between April 28 and May 7. The mangels were planted first and immediately afterward the rutabagas. It is possible that the latter were planted a little too early since they can safely be planted as late as June 1 and require a warmer soil than do the mangles. The seed was drilled with a hand seeder in rows about 30 inches apart. The seed was covered with from three-fourths to one inch of soil. It was found advisable to use plenty of seed, since the yield depended largely upon a good stand. It required from 6 to 8 pounds of mangel seed and 1½ to 2 pounds of rutabaga or carrot seed to the acre.

Cultivating As soon as the plants were up they were cultivated with a wheel hoe. This seemed to be very important, for it controlled the weeds, keeping them from doing damage while the plants were small. As soon as the plants were large enough for the rows to be followed they were cultivated with a one-horse cultivator and later with a two-horse cultivator. This was continued at frequent intervals throughout the season until about the first of August, when the tops were so large that they completely filled the row. It usually was found necessary to do considerable hand hoeing, for it was impossible to get all the weeds with the cultivator. If the weeds could be controlled when small, less hoeing was necessary than otherwise.

Thinning About the time the plants had developed three or four true leaves they were thinned with a hoe to one plant to each 8 to 12 inches in the row. In some places the stand was poor, but no success was obtained by transplanting.

Yields and Varieties Several varieties of both mangels and rutabagas were grown. These were planted in alternate rows and duplicated six or eight times. Where the stand was poor the yields obtained were of course lowered. Some of the seed was obtained from Denmark, some was purchased from England, and some of it was grown in America. The varieties grown and yields obtained are given in Table 1. It will be noted that the yields of the mangels varied from year to year from 23.0 to 35.7 tons per acre and that the rutabagas varied from 13.6 tons to 28.5 tons per acre. The average yield for the six years in which mangels were grown was 28.7 tons per acre; for the five years in which the rutabagas were grown the average yield was 15.9 tons per acre. Sugar beets averaged 15.3 tons and carrots 10.9 tons per acre. During this period the average yield of corn silage was 10.3 tons per acre.

Harvesting The roots usually were harvested during the last two weeks in October. It was found convenient to pull, top, and load them on a wagon as it was driven along the rows. Most of the varieties were easy to pull, since they set out of the ground almost half way. The carrots, however, had to be plowed out. Varieties differed considerably in difficulty of harvesting, the globe varieties being easier to pull than the long varieties.

Storage The roots were stored in a root cellar of 50-ton capacity, built in the basement of the barn. The temperature seldom reached freezing. No provision was made for ventilation except what was obtained through the door and windows. The roots kept fairly well until about the first of February. After that a large number were found to be spoiled, and by the middle of March most of them were thus affected.

Composition For three different years samples were taken of the roots in the field about one month before harvest, again at time of harvest, and at monthly intervals for three months after harvest. In sampling, eight or ten representative roots of each variety were selected in the field, marked, and sampled by means of a cheese trier, a single diagonal boring being taken from each root. These same roots and the same method of sampling were used in subsequent periods. The sampled roots were harvested and handled in the same manner as the remainder. The samples when taken were placed in air-tight glass containers and taken to the laboratory, where they were analyzed according to the customary method of the Association of Official Agricultural Chemists *(1)*. The change in composition of the roots due to storage have been reported in another paper

TABLE 1—*Average yield of root crops and silage grown from 1924 to 1929 at the West Virginia Agricultural Experiment Station*

Varieties	Yield in tons per acre by years						
	1924	1925	1926	1927	1928	1929	Average
Mangels							
Mammoth Prize Long Red .....(A)*	32.8	24.5	40.7	30.5	34.1	27.3	31.7
Golden Tankard .....(E)	27.2	23.1	26.2	22.0	20.7	16.5	22.6
Yellow or Orange Globe .....(A)	33.2	31.2	20.9	25.7	28.6	...	27.9
Danish Sludstrup .....(A)	26.3	31.7	...	27.8	27.4	22.5	27.1
Barres Hinjne V .....(D)	38.7	...	...	...	...	...	38.7
Barres Tystofte V, VI .....(D)	37.9	32.0	...	26.6	27.7	...	31.1
Barres Stryno VI .....(D)	...	32.6	42.5	29.9	35.0	...	35.0
Yellow Globe .....(E)	..	29.0	36.3	...	29.6	22.4	29.3
Barres Rosted, Roskilde VI .....(D)	...	...	48.3	24.4	15.7	...	29.5
Yellow Intermediate .....(E)	...	...	...	...	23.4	17.2	20.3
Red Intermediate .....(E)	...	...	...	...	...	23.1	23.1
Silesian Sugar .....(A)	...	...	...	...	...	31.9	31.9
Average.....	32.7	29.2	35.7	26.7	26.9	23.0	28.7
Rutabagas							
Bangholm Olsgaard V and VI.....(D)	30.3	19.4	22.8	...	...	...	24.2
Bangholm Pajbjerg V .....(D)	26.6	...	...	...	...	...	26.6
Bangholm Hunsballe VI .....(D)	...	15.9	...	...	...	...	15.9
Purple Top Yellow .....(A)	...	16.2	18.7	13.9	11.7	...	15.2
Magnum Bonum .....(E)	...	12.3	15.9	16.7	19.6	...	16.2
Acquisition .....(E)	...	11.1	17.4	10.7	13.3	...	13.1
Bangholm Lyngby VI .....(D)	...	...	21.4	13.1	15.9	...	16.8
Average.....	28.5	15.0	19.2	13.6	15.1	...	17.1
Sugar Beets							
Klein Wanzleben .....(A)	...	...	15.5	18.1	16.7	10.7	15.3
Carrot							
Yellow Belgium .....(A)	...	...	...	7.7	11.7	13.2	10.9
Corn Silage							
Woodburn White Dent .....(A)	7.3	12.9	10.4	12.1	8.6	10.2	10.3

*(A) Seed grown in America.
(D) Seed grown in Denmark.
(E) Seed grown in England.

TABLE 2—*Average percentage composition of different varieties of root crops after two months in storage, and average percentage composition of corn silage*

Variety	No. of years analyzed	Moisture %	Dry matter %	Crude protein %	Ether extract %	Crude fibre %	Nitrogen-free-extract %	Ash %
Mangels								
Mammoth Prize Long Red	3	89.2	10.8	1.2	.06	.8	7.6	1.1
Golden Tankard	3	89.8	10.2	1.3	.05	.8	6.8	1.2
Yellow Orange Globe	3	92.1	7.9	1.2	.08	.7	4.9	1.0
Danish Sludstrup	2	88.3	11.7	1.0	.08	.8	8.7	1.1
Barres Tystofte VI	2	90.0	10.0	1.0	.07	.7	7.2	1.0
Barres Stryno VI	3	91.6	8.4	1.0	.07	.6	5.5	1.2
Yellow Globe	3	92.2	7.8	1.1	.07	.7	4.7	1.2
Barres Rosted Roskilde VI	2	89.7	10.3	1.0	.05	.7	7.5	1.0
Average		90.4	9.6	1.1	.07	.7	6.6	1.1
Rutabagas								
Bangholm Olsgaard VI	2	88.5	11.5	1.9	.11	1.5	6.8	1.1
Bangholm Hunsballe VI	1	89.6	10.4	1.9	.08	1.5	5.3	1.6
Purple Top Yellow	3	89.9	11.0	1.8	.09	1.5	6.3	1.3
Magnum Bonum	3	89.5	10.5	1.6	.10	1.6	5.8	1.4
Acquisition	3	88.9	11.1	1.6	.13	1.6	6.4	1.4
Bangholm Lyngby VI	2	88.7	11.3	1.4	.11	1.7	7.0	1.1
Average		89.0	11.0	1.7	.10	1.6	6.3	1.3
Sugar Beets								
Klein Wanzleben	2	80.3	19.7	1.2	.03	1.1	16.5	0.9
Carrots								
Yellow Belgium	1	84.6	15.4	1.6	.18	1.4	10.9	1.3
Corn Silage	5	76.0	24.0	2.1	.70	5.8	14.0	1.4

from this Station *(9)*, the most marked change being a continuous loss of moisture with, of course, a corresponding percentage increase in dry-matter content and, as a general rule, a percentage increase in all the constituents making up dry matter. The change in moisture content is shown graphically in Figure 1. The percentage of moisture in mangels was found to be approximately 1 percent greater than that in rutabagas.

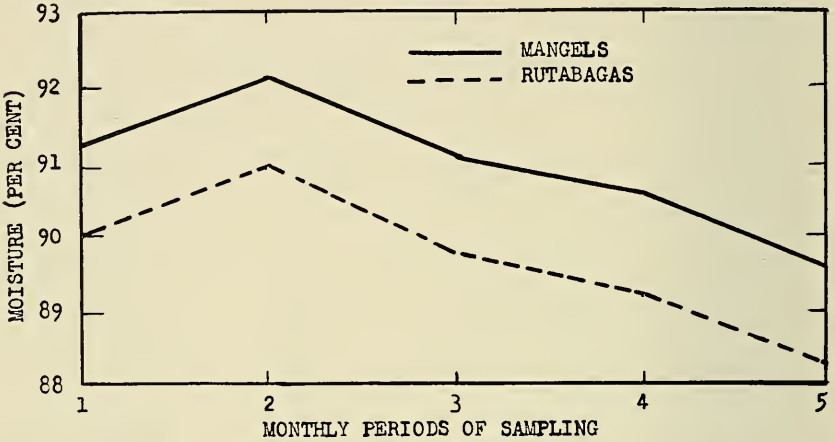

FIG. 1—Moisture content of mangels and of rutabagas from one month previous to harvest until three months after harvest. Average for all varieties for three years

The average percentage composition of the different varieties of root crops after two months of storage, together with that of corn silage, is shown in Table 2. These samples were taken about the last of December in each case, as it was thought that this would be more representative than at earlier or later periods of sampling. It will be noted that there is considerable variation in the dry-matter content of the different varieties of mangels, variations being found from 7.8 to 11.7 percent. The average dry-matter content for eight varieties analyzed a total of 21 times was found to be 9.6 percent. With the exception of the nitrogen-free extract the other constituents varied but little as a result of variety. The rutabagas seemed to vary less than did the mangels. The dry matter varied from 10.4 to 11.5 percent with an average of 11.0 percent, while the other constituents remained fairly uniform. It will be noted also that corn silage contains 2.5 times as much dry matter as do mangels and 2.2 times as much as do rutabagas.

The average yield of dry matter and crude protein per acre is given in Table 3. It will be noted that the mangels produced 566 pounds more dry matter and almost 200 pounds more crude protein than did an acre of corn silage. Sugar beets produced even more dry matter than did mangels.

TABLE 3—*Average yield of total dry matter and total crude protein produced on an acre of corn silage and of root crops*

Crop	Yield per acre	Ave. % dry matter	Ave. % crude protein	Total dry matter per acre	Total crude protein per acre
	(*tons*)			(*lbs.*)	(*lbs.*)
Corn Silage	10.3	24.0	2.1	4944	432.6
Mangels	28.7	9.6	1.1	5510	631.4
Rutabagas	17.1	11.0	1.7	3762	581.4
Sugar Beets	15.3	19.7	1.2	6028	367.2
Carrots	10.9	15.4	1.6	3357	348.8

COST OF PRODUCTION

While greater yields of both dry matter and crude protein were obtained in an acre of mangels than in an acre of corn used for silage, yet the cost of producing this dry matter and protein was much higher. The production units and the cost of raising an acre of mangels and an acre of silage are shown in Table 4.* The total cost of producing an acre of corn was $73.03, while that of producing an acre of mangels was $142.15. This seems high in both cases but the cost included a very heavy application of manure, which was done because an abundance of this fertilizer was available.† The cost of producing 100 lbs. of dry matter and crude protein in silage was only 57 percent and 75 percent, respectively, as much as with mangels.

TABLE 4—*Cost of producing an acre of mangels as compared to an acre of corn silage*

	Corn silage			Mangels		
	Units	Rate	Cost	Units	Rate	Cost
Man labor	103 hrs.	25c	$25.75	302 hrs.	25c.	$75.50
Team labor	34 hrs.	25c	8.50	53 hrs.	25c	13.25
Tractor labor	6.5 hrs.	1.00	6.50	7 hrs.	1.00	7.00
Seed	7 lbs.	.04	.28	8 lbs.	.30	2.40
Manure	15 tons	2.00	30.00	20 tons	2.00	40.00
Fertilizer	250 lbs.	16.00	2.00	400 lbs.	20.00	4.00
Total cost per acre			$73.03			$142.15
Cost of 100 lbs. of dry matter			1.48			2.58
Cost of 100 lbs. of crude protein			16.80			22.51

PLAN OF EXPERIMENT

FEEDING TRIALS

Four feeding trials were conducted in which mangels were compared with corn silage for the production of milk. Altogether 31 animals were used, two lots of four cows each comprising the experimental groups for each of the four trials. In the last trial one of the cows was eliminated because of an unusual decline in production resulting from advanced lactation. The groups for this year therefore were divided with four animals in one lot and three in the other.

* These records were kept for only one year, but are thought to be fairly representative of the other years.

† There was no attempt to measure the value of the manure and it might have been more profitable to have added less. However, this item would have made little difference in the comparison. The greatest difference is found in the amount of hand labor required in the thinning and weeding of the mangels.

Each year the two lots were divided as equally as possible in regard to breed, weight, age, stage of gestation and lactation, daily milk production, and butterfat percentage.

In the first trial the entire experiment covered a period of 56 days, divided into 21-day experimental periods, each of which was preceded by a 7-day preliminary or transition period. For the trials of the last three years the experimental period was increased to 76 days, consisting of two 28-day periods preceded each by a preliminary or transition period of 10 days.

The single reversal method of feeding was employed in all four trials. By this plan the rations were reversed at the end of the first experimental period (21 or 28 days), so that the animals received each of the rations for an equal portion of the time of the experiment.

Alfalfa hay was fed in all periods. The same grain ration was fed to each group of cows throughout the experiment. It consisted of cornmeal, 600 lbs.; ground oats, 200 lbs.; wheat bran, 200 lbs.; cottonseed meal, 200 lbs.; and salt, 12 lbs.

To this ration was added corn silage or mangels. When corn silage was fed the ration was designated as the silage ration; when mangels were included it was designated as the mangel ration.

In feeding the aim was to follow, in so far as possible, recommended practices. The alfalfa hay was fed at the rate of one pound to every 100 lbs. of live weight and the silage at the rate of three pounds to every 100 lbs. of live weight. The mangels were apportioned in amounts of about 2½ times that of the corn silage. The exact ratio varied according to the dry matter content from 1:2.20 to 1:2.51. The ratio of dry matter in corn silage to the dry matter of mangels as computed from the average anlyses obtained was approximately 1:2.5. The grain ration was fed in proportion to milk production as calculated from the Morrison Feeding Standard. The daily ration for each animal was computed at weekly intervals, the computations being based upon the average daily milk production and average weight of the cow for the preceding 7-day period. Each animal was weighed on the 2nd, 5th, and 7th day of the weekly periods, the average of these weights being taken as the weight upon which to compute the feed requirement for the following 7 days. Weighings were made at approximately the same time of day.

The cows were milked three times daily and the milk weights recorded after each milking. Composite milk samples were taken for each animal. These samples were tested for butterfat by the Babcock method at the end of each 7-day period.

All feed fed to and refused by the animals was weighed daily. Silage, mangels, and grain were fed three times per day immediately before milking; hay was fed at one feed, immediately after the evening milking. Water was available in individual drinking cups. During the last two trials the daily water consumption was measured by means of water meters attached to the cups.

Results of First Feeding Trial

Eight cows were used in this trial and as stated previously, there were two experimental periods, 21 days in length, with a 7-day preliminary and a 7-day transition period. The results of this trial are given in Table 5. The mangels were fed and consumed at the rate of 2.44 pounds for each pound of silage. The amount of hay consumed did not differ much in the two rations. Since the mangel group produced a little more milk than the silage group they consumed a little more grain. The production of milk averaged 1.2 lbs. per cow per day greater for the mangel group than for the silage group during the 42 days of

TABLE 5—*Results of first feeding trial*

Item	Silage ration		Mangel ration
Number of animals used	8		8
Length of trial (days)	42		42
Lbs. of silage consumed per day	36.8		..
Lbs. of mangels consumed per day	..		89.7
Ratio of mangels to silage consumed	1	to	2.44
Lbs. of hay consumed per day	12.3		12.1
Lbs. of grain consumed per day	9.1		9.5
Lbs. of dig. crude protein consumed per day	2.91		3.26
Lbs. of dig. nutrients consumed per day	19.7		20.0
Lbs. of milk produced per day	26.5		27.7
Percentage fat in milk	3.41		3.26
Lbs. butterfat produced per day	.90		.90
Lbs. of 4 percent milk produced per day	24.1		24.6
Lbs. gained in weight per day	.15		.56

the trials. It will be noted, however, that the butterfat percentage was lower during the feeding of mangels than during the feeding of silage, so that the actual difference in total butterfat was very slight. This depressing effect of the mangel ration on the butterfat percentage was observed in each of the four trials. The difference, however, was not great in any case. In weight the silage group made a gain of 0.15 lb. per day, while the mangel group made a gain of 0.56 lb. per day.

Results of Second Feeding Trial

During this trial eight cows were employed. The two experimental periods were 28 days in length, preceded by a 10-day preliminary or transition period. The results of this trial are given in Table 6. It will be noted that the mangels were consumed at the rate of 2.2 lbs. for each pound of corn silage. The amount of hay consumed was not greatly different for the two groups, but the silage group consumed a little more grain than the mangel group. The daily amount of digestible protein and total digestible nutrients consumed was not greatly different for the two groups.

The production of milk again was a little in favor of the mangel group, but the lower fat percentage reduced the fat production, with the result that there was little difference in the total amount of fat produced by the two groups or in the amount of milk when converted

TABLE 6—*Results of second feeding trial*

Item	Silage ration		Mangel ration
Number of animals used	8		8
Length of trial (days)	56		56
Lbs. of silage consumed per day	37.1		..
Lbs. of mangels consumed per day	..		81.7
Ratio of silage to mangels	1	to	2.20
Lbs. of hay consumed per day	12.0		12.2
Lbs. of grain consumed per day	10.7		10.1
Lbs. of dig. crude protein consumed per day	3.10		3.28
Lbs. of dig. nutrients consumed per day	20.79		19.93
Lbs. of milk produced per day	35.5		36.1
Percentage of butterfat in milk	3.25		3.18
Lbs. butterfat produced per day	1.15		1.15
Lbs. of 4 percent milk produced per day	31.5		31.7
Lbs. gained in weight per day	.31		—.12

to the 4 percent basis. The difference in gain in weight between the two groups amounted to less than one-half pound per day per cow and was in favor of the silage group.

Results of Third Feeding Trial

The third trial was conducted the same as the second trial. The results are given in Table 7. The mangels were consumed at the rate of 2.4 lbs. for each pound of silage. Slightly more hay and less grain was consumed when the cows were on the silage ration. The effect of the two rations on milk and butterfat percentage as measured over the two 28-day periods was similar to that of the two previous trials. The yield of milk was 1.1 lbs. per day greater for the mangel group than for the silage group, the fat percentage was decreased 0.09 percent, and the total butterfat produced was about the same for the two groups. When converted to the 4 percent basis the difference was not great. The cows when on the mangel rations decreased slightly in weight but again the difference is only about one-half pound for each cow per day in favor of those on the silage ration.

TABLE 7—*Results of third feeding trial*

Item	Silage ration		Mangel ration
Number of animals used	8		8
Length of trial (days)	56		56
Lbs. of silage consumed per day	37.0		..
Lbs. of mangels consumed per day	..		88.7
Ratio of mangels to silage consumed	1	to	2.40
Lbs. of hay consumed per day	12.3		12.0
Lbs. of grain consumed per day	8.7		8.8
Lbs. of dig. crude protein consumed per day	2.87		3.05
Lbs. of dig. nutrients consumed per day	19.43		19.35
Lbs. of milk produced per day	32.6		33.7
Percentage of butterfat	3.28		3.19
Lbs. butterfat produced per day	1.07		1.08
Lbs. of 4 percent milk produced per day	29.1		29.7
Lbs. gained in weight per day	.47		—.08

Results of Fourth Feeding Trial

The fourth trial was conducted in the same way as the second and third trials with the exception that, as stated previously, one cow was dropped from the experiment. The data from this cow were not considered. Results are given in Table 8. The mangels were fed at a higher level than in any of the previous trials. The rations were computed so that the mangels were fed at the rate of 2.51 lbs. to one pound of silage. One cow was fed as much as 125 lbs. of mangels per day. They were readily eaten without any injurious effects, and it is possible that even a larger amount would have been consumed if offered. The increased consumption of mangels made possible a slightly lower level in grain consumption than in the previous trials. The amount of hay consumed was not greatly different for the two groups. This trial was the only one of the four that showed greater milk production for the silage group. The difference, however, was slight. The fat percentage again was slightly lower with the mangel group and there was little difference in the total fat; neither was there much difference when converted to a 4 percent basis. The change in live weight in this trial was slightly in favor of the mangel group. The difference, however, was not great, amounting to only about 1/10 of a pound per cow per day.

TABLE 8—*Results of fourth feeding trial*

Item	Silage ration		Mangel ration
Number of cows used	7		7
Length of trial (days)	56		56
Lbs. of silage consumed per day	34.1		..
Lbs. of mangels consumed per day	..		85.6
Ratio of mangels to silage consumed	1	to	2.51
Lbs. of hay consumed per day	11.3		11.4
Lbs. of grain consumed per day	7.5		6.6
Lbs. of dig. crude protein consumed per day	2.58		2.77
Lbs. of dig. nutrients consumed per day	17.49		17.16
Lbs. of milk produced per day	25.3		25.1
Percentage of fat	3.69		3.67
Lbs. butterfat produced per day	.93		.92
Lbs. of 4 percent milk produced per day	24.1		23.8
Lbs. gained in weight per day	.66		.80

Summary of the Feeding Trials

The summary of the four feeding trials is given in Table 9. The average daily consumption per animal for the 31 cows when fed on the silage ration was 36.3 lbs. of corn silage, 12 lbs. of hay, and 9.1 lbs. of the grain ration, while the same cows when on the mangel ration consumed daily 86.2 lbs. of mangels, 11.9 lbs. of hay, and 8.9 lbs. of grain. The mangels were fed at the rate of 2.37 lbs. for each pound of silage. When converted to digestible crude protein and total digestible nutrients by using the average figures as given by Henry and Morrison, it is found that the daily amount consumed when the cows received the silage ration was 2.86 lbs. digestible protein and 19.36 lbs. of digestible nutrients, and when fed the mangel ration they consumed 3.12 lbs. digestible protein and 19.12 lbs. of total

TABLE 9—*Summary of results of the four feeding trials*

Item	Silage groups	Mangel groups
Number of cows used	31	31
Length of trial (days)	210	210
Lbs. of silage consumed per cow per day	36.3	..
Lbs. of mangels consumed per day	..	86.2
Ratio of mangels to silage consumed	1 to	2.37
Lbs. of hay consumed per day	12.0	11.9
Lbs. of grain consumed per day	9.1	8.9
Lbs. of dig. crude protein consumed per day	2.86	3.12
Lbs. of dig. nutrients consumed per day	19.36	19.12
Lbs. of milk produced per day	30.4	31.1
Percentage fat in milk	3.39	3.28
Lbs. butterfat produced per day	1.03	1.02
Lbs. of 4 percent milk produced per day	27.6	27.7
Lbs. gained in weight per day	.41	.25

digestible nutrients. The average daily production of the 31 cows on the silage ration was 30.4 lbs. of 3.39 percent milk, and on the mangel ration 31.1 lbs. of 3.28 percent milk. When converted to 4 percent milk by the formula suggested by Gaines and Davidson *(4)* it is found that under the conditions as fed, the cows produced an equivalent of 27.6 lbs. when fed the silage ration and 27.7 lbs. when fed the mangel ration. In comparing the fat percentage of the individual cows it was found that of the 31 animals, 21 showed a decreased fat percentage, three showed no difference in the fat percentage, and seven showed an increased fat percentage while on the mangel ration. These results would indicate that as a rule the mangel ration as compared to the silage ration had a depressing effect upon the butterfat content of the milk. Although there was an increased milk flow from the cows when fed mangels, the lowered fat test of the milk was sufficient to decrease the amount of butterfat to slightly below that of the corn silage.

There was a slight difference in gain in weight in favor of the cows on silage.

Water Consumed During the last two trials, record of the exact amount of water consumed each day by the cows in each group was kept by means of a water meter attached to the individual watering cup of each cow. The moisture content of the mangels and silage also was ascertained and in this way it was possible to calculate the amount of water that each cow was receiving per day. The data obtained are recorded in Table 10. It will

TABLE 10—*Amount of water consumed on different rations*

Water consumption	Silage ration		Mangel ration	
	Lbs.	Percent of total	Lbs.	Percent of total
Water consumed from drinking cup per cow per day	83.1	7.54	52.2	39.8
Water consumed from succulent feed per cow per day	27.1	24.6	78.9	60.2
Total water consumed per cow per day	110.4	100.0	131.1	100.0
Water consumed for each pound of 4 percent milk produced	4.1		4.9	

be seen that the cows consumed more water from their cups when fed silage than when fed mangels, but the total amount of water consumed was considerably greater when the cows were fed mangels than when fed silage. When fed mangels the cows consumed a total of 4.9 lbs. of water for each pound of 4 percent milk produced and when fed silage, they consumed only 4.1 lbs. of water for each pound of milk produced. This might be an explanation of the lower fat percentage obtained when the cows were fed mangels.

SUMMARY AND CONCLUSIONS

Four feeding trials were run in which mangels were compared with corn for milk production when fed on the dry-matter basis. As far as possible all other factors were balanced in the two groups, and the single reversal feeding method was used so that the same animals might receive the different rations. Data were kept also on the amount of water consumed from the drinking cups and the amount obtained from the succulent feed.

For five years, data were obtained on the yields of corn silage and different varieties of root crops. Samples of the root crops were taken and analyzed at monthly intervals during the season, and a sample of the corn silage also was analyzed during the season. From these data it was possible to figure the average yield per acre of dry matter and crude protein produced by the various root crops and corn silage. The units entering into the cost of an acre of corn and an acre of mangels were also recorded. The following conclusions were reached:

The results of these feeding trials show that on the dry-matter basis there was very little difference in the feeding value of mangels and corn silage for milk production. The cows produced a little more milk when fed mangels than when fed corn silage, but the fat percentage was lower. When the milk was converted to a 4 percent basis there was very little difference in the value of the two feeds.

The cows when fed mangels consumed less water from their drinking cups but obtained more total water than they did when they were fed corn silage.

Mangels and other root crops can be grown successfully in West Virginia under the conditions herein described. On soil that yielded an average of 10.3 tons of silage per acre, an average yield was obtained of 28.7 tons of mangels, 17.1 tons of rutabagas, 15.3 tons of sugar beets, and 10.9 tons of carrots.

Under average conditions as described, an acre of corn silage produced 432.6 lbs. of crude protein and 4944 lbs. of dry matter as compared to 631.4 lbs. of crude protein and 5510 lbs. of dry matter for mangels, 581.4 lbs. crude protein and 3762 lbs. of dry matter for rutabagas, 367.2 lbs. crude protein and 6028 lbs. dry matter for sugar beets, and 348.8 lbs. crude protein and 3357 lbs. of dry matter for carrots.

Under the conditions as described, the cost of producing 100 lbs. of dry matter in corn silage was 57 percent as much as with mangels, and the cost of producing 100 lbs. of crude protein was 75 percent as high as with mangels.

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